

DEVELOPED MAGNETIC PROPERTIES OF MO^{6+} SUBSTITUTED LITHIUM FERRITES

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ABSTRACT

The present study reports the developed magnetic properties of high valency non-magnetic ion Mo^{6+} substituted lithium ferrites. The samples with compositional formula $[\text{Li}_{(1+3y)/2}\text{Mo}_y\text{Fe}_{2.5-5y/2}]\text{O}_4$ (where $y = 0.05$ to 0.5 in steps of 0.05) were prepared by standard Ceramic method and sintered at 1200°C . The Curie Temperatures (T_c) were measured and found gradually decreasing up to $y=0.25$ from where again the Curie Temperature gradually increased to maximum 702°C (highest) at $y = 0.5$. Saturation magnetization, Coercivity, remanent magnetization were studied as a function of composition. Saturation magnetization is found to maximum 67.4 emu/gm at $y = 0.05$ then decreasing gradually up to $y = 0.25$ then again gradually increasing with continuous increasing of molybdenum. Saturation magnetization and Curie temperature showing direct relation and saturation magnetization is inversely proportional to coercivity. Initial permeability also increased maximum up to $y = 0.10$ then decreases continuously increasing with Molybdenum.

KEYWORDS: Lithium Ferrite, Curie Temperature, Magnetic Properties

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1. INTRODUCTION

Lithium ferrites are very important ferrites in materials science due to a lot of applications in electrical, magnetic and microwave components as different ways such as Circulators, memory cores, Phase shifters isolators, gyrators, in micro wave latching devices, as core materials of inductors, transformer cores, as memory devices in computers, cathode material in lithium batteries [1-5] etc owing to their attractive properties, some of them are magnetically like high saturation magnetization, high Curie temperature, better temperature stability of saturation of magnetization, excellent rectangular loop characteristics, excellent flat profile at high frequencies [6]. In addition to the ease of fabrication and low cost [7] of having these properties lead to more advantages over other spinel structure [6].

The magnetic properties change rapidly with various compositions in lithium ferrites due to arrangements of cations on the two sites A and B and causing difference in magnetic moments between the two sites. The cation distributions depend on stoichiometry as well as temperature, atmosphere, pressure etc. are control over cation distribution and oxygen parameter provide a means of developing the desired physical properties of their proper use in industry [8].

In the present study, to study how the non-magnetic high valancy Mo^{6+} ion influence on magnetic properties presented in this paper. Lithium ferrites with Molybdenum content are not easily formed the samples unless they are maintained under the moisture less low pressure, and sintering temperature with appropriate rate of heating and cooling.

2. EXPERIMENTAL PROCEDURE

The ferrite samples with compositional formula $[\text{Li}_{(1+3y)/2}\text{Mo}_y\text{Fe}_{2.5-5y/2}]\text{O}_4$ with $0.05 \leq y \leq 0.5$ ('y' is in steps of 0.05) were prepared by conventional standard ceramic method. Appropriate proportionate AR grade Li_2CO_3 , MoO_3 , Fe_2O_3 were taken in an agate mortar and thoroughly ground for 6 hrs with added a methanaol and ground until drying. The dried mixture was calcinated at 625°C for 4 hrs. The related powder was ground again for 6 hrs and granulated using a small amount of PVA binder. Finally pellets and toroidal samples were pressed at 5 tones / cm^2 with electrical pressing machine used in measurements of magnetization along with initial permeability. The pellet samples were finally sintered at 1200°C for 4 hrs for obtaining dense material. The samples were cooled in the furnace at the rate of $3^\circ\text{C}/\text{min}$. The magnetization measurements were carried out using a Vibrating Sample magnetometer (VSM, Lake Shore 744) at room temperature with an applied maximum magnetic field of 3.5 KOe to reach saturation values.

Curie temperature measurements were performed by using impedance analyzer with a laboratory built oven and a thermo coupled based thermometer. Initial permeability of toriode shaped samples were performed with impedance Analyzer [model HP4192ALF] and calculated using the formula $\mu = L/L_0$, where L_0 is the air core inductance using the dimensions of the coil.

3. MAGNETIC PROPERTIES

The magnetic moment in ferrites is mainly due to the uncompensated electron spin of the individual ion and the spin alignments in the two sublattice A and B which are arranged antiparallel. There by the net magnetic moment is given by the sum of the magnetic moments (i.e) $M = M_B - M_A$. According to Neel's model saturation magnetization for $\text{Li}_{0.5}\text{Fe}_{2.5}\text{O}_4$ is 69.8emu/gm [9] and this value of magnetization agrees well with the experimentally extrapolated value [10].

From the Table (1) the saturation magnetizations is almost agrees well with these values for $y=0.05$, it is observed that the saturation magnetization is decreased up to 0.25 and then increased again up to $y = 0.5$ with continuous adding of molybdenum. Hysteresis loops are plotted in Fig.1 and indicates that Li-Mo are soft ferrites.

According to Neel's molecular field model [9], the net magnetic moment of the ferrite is the sum of the magnetic moments of two super exchange interacted sub lattices A and B. In this study, cationic distribution, Li^{1+} and Mo^{+6} are the non-magnetic ions hence they do not contribute to the sublattice magnetization [11-13]. For Li-Mo ferrites, Li^{1+} substitution for Fe^{3+} ions at A site and at B site Fe^{3+} ions are replaced by non-magnetic Li^{1+} and Mo^{6+} ions, there by the net magnetization is decreasing from the two sublattices (A and B) magnetization.

It is seen in the Table 1 the magnetization values are decreased up to $y = 0.25$ from where increasing. i.e the values in the range between 67.4 and 62.50 emu/gm. This is may be due to fact that the migration of cations of from A site to B site and B site to A site similar type of study Trivedi et al [14] and partial reduction of Fe^{3+} to Fe^{2+} this is due to, for dense material the samples are sintered at 1200°C there by Oxygen dissociation and lithium volatility occurs resulting in formation of non-stoichiometric composition. The consequence is reduction of Fe^{3+} ions into Fe^{2+} ions [15]. This was confirmed by photo chemical reduction method in Redox titration. The same reason can applied to a similar behavior shows in Curie temperatures (T_c) which are also decreased up to $y = 0.20$ and then again increasing to maximum 702°C at

$y=0.5$ with continuous increasing content of molybdenum. The curie temperature for $y=0.05$ agrees good with pure ferrite value [16].

The Coercive force (H_c) is an independent parameter which can be altered by heat treatment or deformation and hence it is not dependent on saturation magnetization [11]. It is increased up to $y=0.35$ and then decreases with molybdenum and the variation in the range of 1.527 to 7.540 Oe. The remanent magnetization is also an independent parameter, hence not dependent on saturation magnetization (M_s) and Coercive force (H_c) [11]. The values of remanent magnetization varied in the range 0.31 to 3.46 emu/gm.

Initial permeability was studied up to 13MHz, it is increasing up to $y=0.10$ and then gradually decreasing up to $y=0.5$ with further increase of molybdenum substituted concentration. It can be shown in Figure (3). Similarly compositional variation can be seen in Figure (2) at 1 kHz. From Figure (3) all the specimens were shown the flat profile from 0.001MHz to 10MHz from logarithmic frequency, further from where slightly increases with frequency then raised to maximum at 13MHz. This is due to fact that that the onset of resonance and then may fallen to low values with further increasing frequency like similar behaviour as indicated in Yen-Pei et al [12]. This laps here is due to this study were made up to 13 MHz. The flat profile over certain range of frequency is an attractive in magnetic applications. The dispersion of initial permeability at low frequency is attributed to domain wall oscillations which were drifting towards the higher side with increase of molybdenum causing decreasing in initial permeability. Initial permeability is depending on the grain size, saturation magnetization, magneto crystalline anisotropy and porosity [17-18]. The maximum increase at $y=0.15$ is may be due to the fact that porosity has lowest than all other specimens and further attributed to grain size and crystalline anisotropy.

4. CONCLUSIONS

Interesting magnetic properties of molybdenum have been studied systematically. Saturation magnetization and Curie temperatures were found and showed a similar behaviour and direct relation between them. Decreasing and increasing in magnetization and Curie temperature values are attributed to depend on reduction of Fe^{3+} to Fe^{2+} with inverse proportionate and on cations arrangement and rearrangements. The arrangements and rearrangements due to migration of cations from A site to B site and B site to A site seems to redistribution taken place. Remanent magnetization and coercivity are independent parameters not depend on saturation magnetization. Initial permeability of all the specimens were showed flat profile over certain range of frequencies. Increased initial permeability for composition $y=0.05$ might be attributed to grain size and anisotropy constant and low porosity. The rapid increase at 13MHz is attributed to the onset of resonance frequency then further considered a fall down.

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Figure Caption

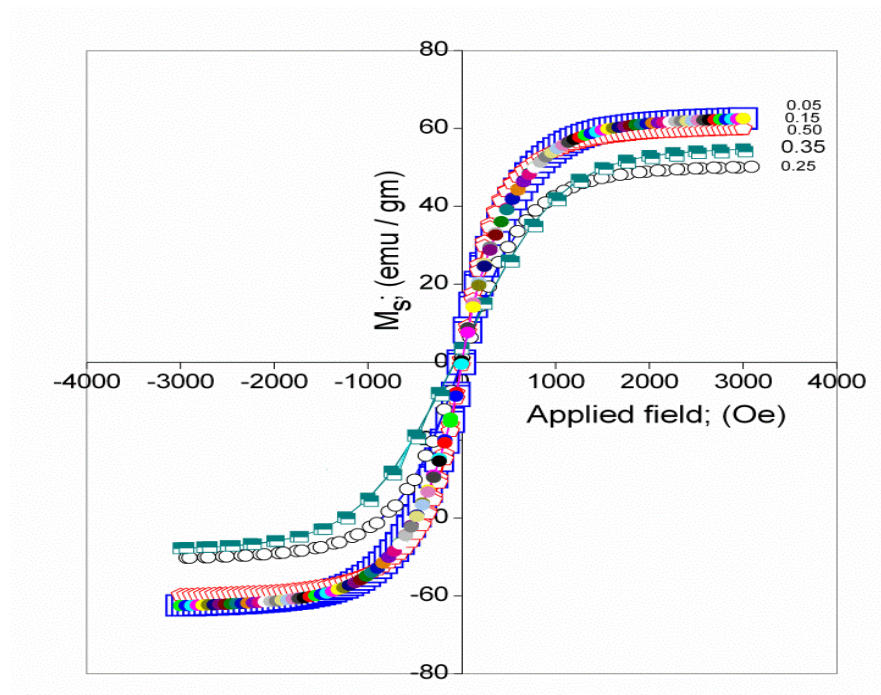


Figure 1: Variation of Magnetization with Applied Field for Different Content of Mo

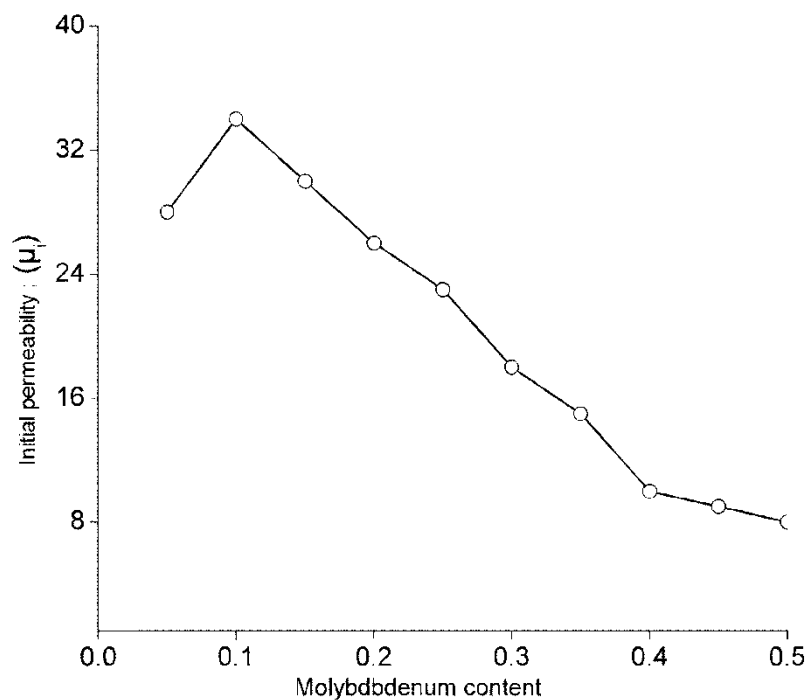


Figure 2: Variation of Initial Permeability with Content of Mo

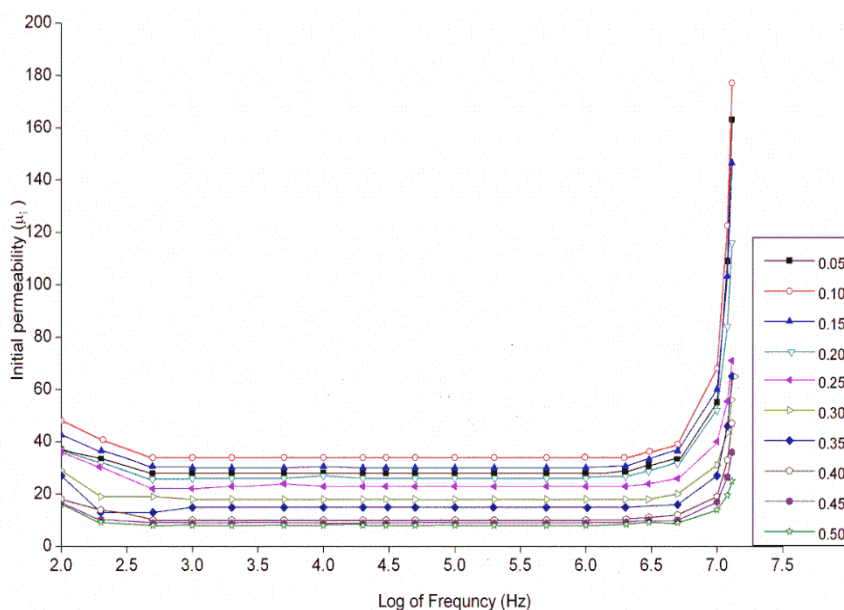


Figure 3: Initial Permeability as a Function of Frequency for Molybdenum-Substituted Lithium Ferrites

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